

COUPLER DETECTOR

BACKGROUND

- [0001] Cellular phone handsets are required to set transmit power to within a specified precision. There are two predominant techniques. The first is the in factory calibration performed when the handset is being manufactured. In calibration, the handset is measured to ascertain the output power under various circumstances, and a table of the results is generated and stored within the handset. This table is used to set the power per the direction of the system. The accuracy of the power setting is then determined by how thoroughly this calibration is accomplished. This technique is not capable of responding to changes in the performance of the handset.
- [0002] The second technique is sample and detect. The power out of the transmit portion is sampled and detected. The second technique requires a coupler, detector, and signal processing to measure the detected voltage as will be further described. This requires that a form of calibration be performed, but the detection circuit will accurately reflect any subsequent changes in the performance of the handset.
- [0003] Figure 1 schematically illustrates how a coupler works. Any two conductors, e.g. transmission lines, sufficiently near one another will function as a coupler. Power delivered into a first transmission line will couple into a parallel second transmission line, and flow in a direction *opposite* to that in the first transmission line. The amount of coupling is a function of the separation between the two transmission lines and the multiple of wavelengths that the separation embodies.
- [0004] Figure 2 illustrates a dual directional coupler. The coupler can detect both incident and reflected power.
- [0005] Using either prior art coupler, the detected power is then delivered to a detector diode. The diode rectifies the power and generates a DC level. This DC level is processed according to the system needs. The detected value is used to adjust the power level as required.
- [0006] The process technology used to implement the coupler sets the minimum separation between the through conductor, e.g. first transmission line, and the coupled conductor, e.g. second transmission line. This minimum separation

determines the minimum length to achieve the desired coupling. To illustrate, driving a diode directly requires about 15dBm at 1 to 2 GHz, the range of interest for handsets. If the amplifier is transmitting 1W (30dBm), then the coupler must provide 15dB of coupling. This requirement sets the minimum length of the coupler in any particular process technology.

- [0007] There are two loss mechanisms in a coupler. The first is the ideal loss associated with the coupled power. This power leaves the through path and enters the coupled path. When half the power is coupled in a 3dB, the through loss is at least 3dB. In a 15dB coupler, the through loss is at least 0.14dB.
- [0008] The second loss mechanism is resistive. The metals and dielectrics used in a coupler are inherently lossy. Consequently, the longer the through transmission line is the higher the loss. Figure 3 shows the ideal coupler loss vs. coupling for a commercially available ceramic coupler supplied by AVX Inc.
- [0009] Couplers are available in many form factors. The largest are instrument grade, made of machined metal, operable over many octaves. The smallest are built on ceramic, covering perhaps one octave usefully, e.g. small ceramic AVX 15dB coupler having 0.35dB loss at 2GHz. To implement the detector function, the circuit includes the ceramic coupler, external diodes, a biasing network for the diodes, bypass capacitors, and terminating resistors, if needed. The resulting network is large and unwieldy.

SUMMARY

- [0010] The present invention is a coupler and detector integrated on a semiconductor substrate, e.g. Gallium Arsenide or Silicon. Semiconductor processing allows for small trace and space rules. The tighter design rules provide for tighter coupling than can be achieved by ceramic processes. The greater coupling allows for a shorter through line and with less loss, thus closer to ideal coupling. The semiconductor substrate supports the addition of whatever supporting components are required to complete the detecting function, such as diodes, transistors, resistors, capacitors and interconnections.

BRIEF DESCRIPTION OF THE DRAWINGS

- [0011] Figure 1 schematically illustrates how a coupler works.
- [0012] Figure 2 illustrates a dual directional coupler of the prior art.
- [0013] Figure 3 shows the ideal coupler loss vs. coupling for a commercially available ceramic coupler.
- [0014] Figure 4 illustrates an embodiment of the present invention.
- [0015] Figure 5 illustrates an alternate embodiment of the present invention.
- [0016] Figure 6 illustrates an alternate embodiment of the present invention.

DETAILED DESCRIPTION

- [0017] The present invention is a coupler and detector integrated on a semiconductor substrate, e.g. GaAs. Semiconductor processing allows for small trace and space rules on the order of less than 3 μ m horizontal and less than 1 μ m vertical. The tighter design rules provide for tighter coupling than can be achieved by ceramic processes. The greater coupling allows for a shorter through line and with less loss, thus closer to ideal coupling.
- [0018] The entire circuitry for detecting power may be fabricated on the same die. This provides two benefits. First, it greatly reduces the size of the detection function. Second, it supplies a new design regime wherein coupler loss can be traded off with bias current to increase the overall efficiency of the handset.
- [0019] As an example, to provide 1W (30dBm) from a 50% efficient power amplifier, 571 mA from a 3.5V supply is required when there is no coupler. If the 15dB coupler has 0.35dB of loss, the amplifier must deliver 30.35dBm, at the cost of 619 mA. Thus, the coupler requires an additional consumption of 48mA. Because one can integrate the coupler and detector, the loss in the coupler can be reduced while the detected output can be maintained. For instance, if the loss is reduced to 0.15dB, resulting in a coupling of 25dB, one can use a 10dB amplifier to bring the equivalent coupling back to 15dB. The power amplifier is now required to provide 30.15dBm, and so requires 591mA. This amplification would require perhaps 3mA, substantially less than the 28mA difference between 619mA and 591mA.

- [0020] The power detection function is made significantly smaller and more efficient by using an active semiconductor substrate, e.g. GaAs. This substrate can contain the coupler, the detector diodes, the required passive devices for biasing and bypassing, and transistors for amplification.
- [0021] Figure 4 illustrates an embodiment of the present invention 10. A coupler 12 is serially connected to a detector 14. The coupler 12 is further connected to a terminating resistor 16. The coupler 12, detector 14, and terminating resistor 16 are integrated on a unitary semiconductor substrate 18.
- [0022] Figures 5 and 6 disclose embodiments where amplification is used to trade off the loss in coupler for the current required by this amplification, reducing the overall requirement for transmission.
- [0023] Figure 5 illustrates an alternate embodiment of the present invention 10'. A linear amplifier 20 serially connects between a coupler 12 and a detector 14. Terminating resistors 16 are added as needed. All of the components are integrated on a unitary substrate 18.
- [0024] In operation, the linear amplifier 20 amplifies the output signal of the coupler allowing for a coupler with less coupling, and thus less loss.
- [0025] Figure 6 illustrates an alternate embodiment of the present invention 10''. A coupler 12 serially connects to a detector 14 at node A. A charge pump 22 connects to the node A. Terminating resistors 16 are added as needed. All of the components are integrated on a unitary substrate 18.
- [0026] In operation, the charge pump 20 increases the voltage at node A. This compensates for the possibly lower coupling of an integrated coupler 12.